The Solutions Network

Rochester, New York

Challenges in Security and Resilience of Electricity Infrastructure

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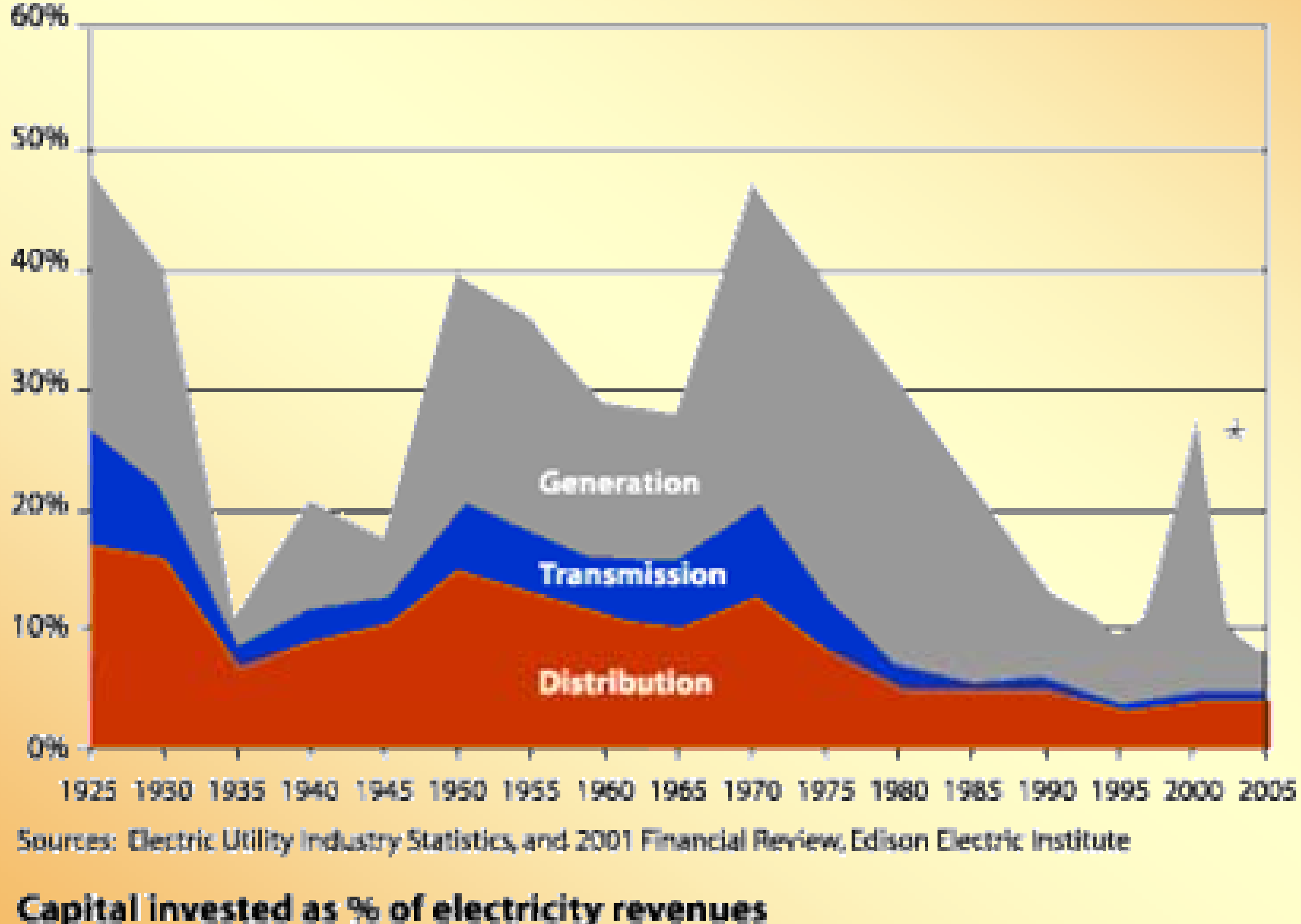
Challenges

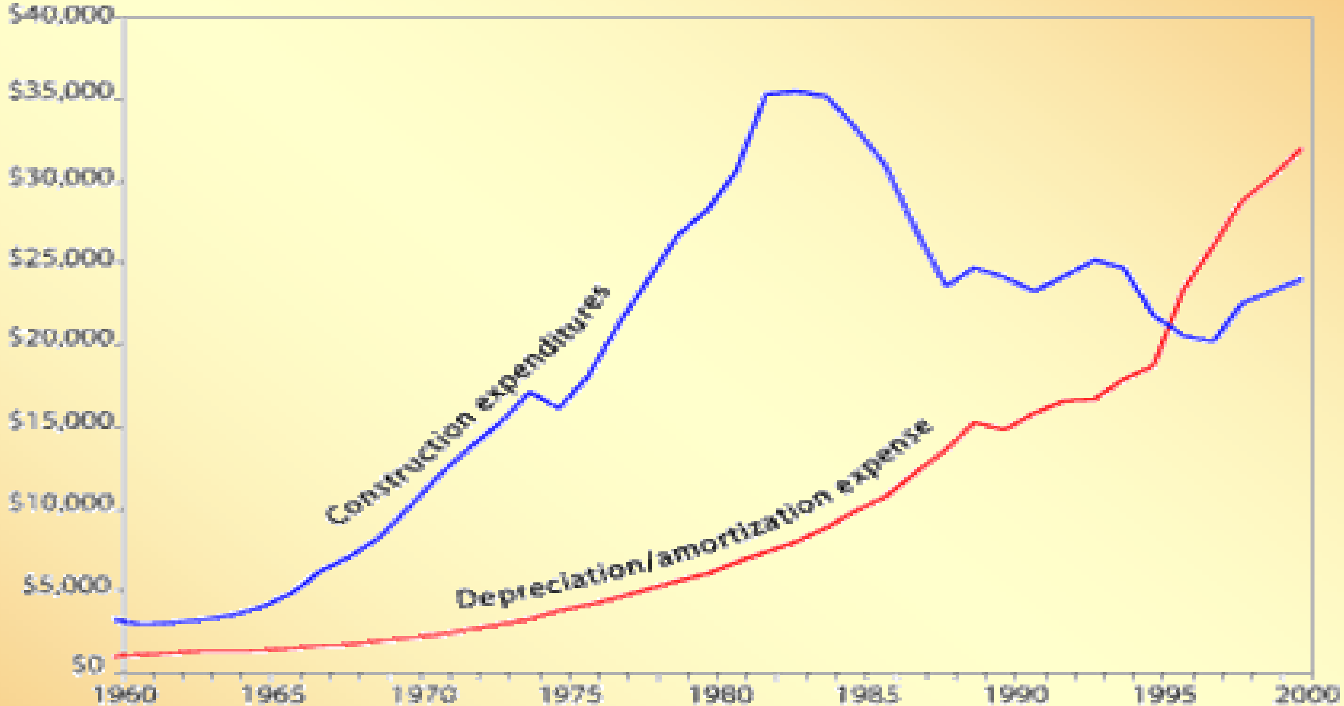
- Will the electricity system evolve to support the digital society of the 21st century, or be left behind as an industrial relic of the 20th century?

- How can we redesign, retrofit, and upgrade the electro-mechanically controlled system into the ideal grid for the future?

Capital Invested as % of electricity revenue



Utility construction expenditures



Utility construction expenditures and depreciation/amortization expense

In recent years, the investor-owned utility industry's annual depreciation expenses have exceeded construction expenditures. The industry is now generally in a "harvest the assets" mode rather than an "invest in the future of the business" mode.

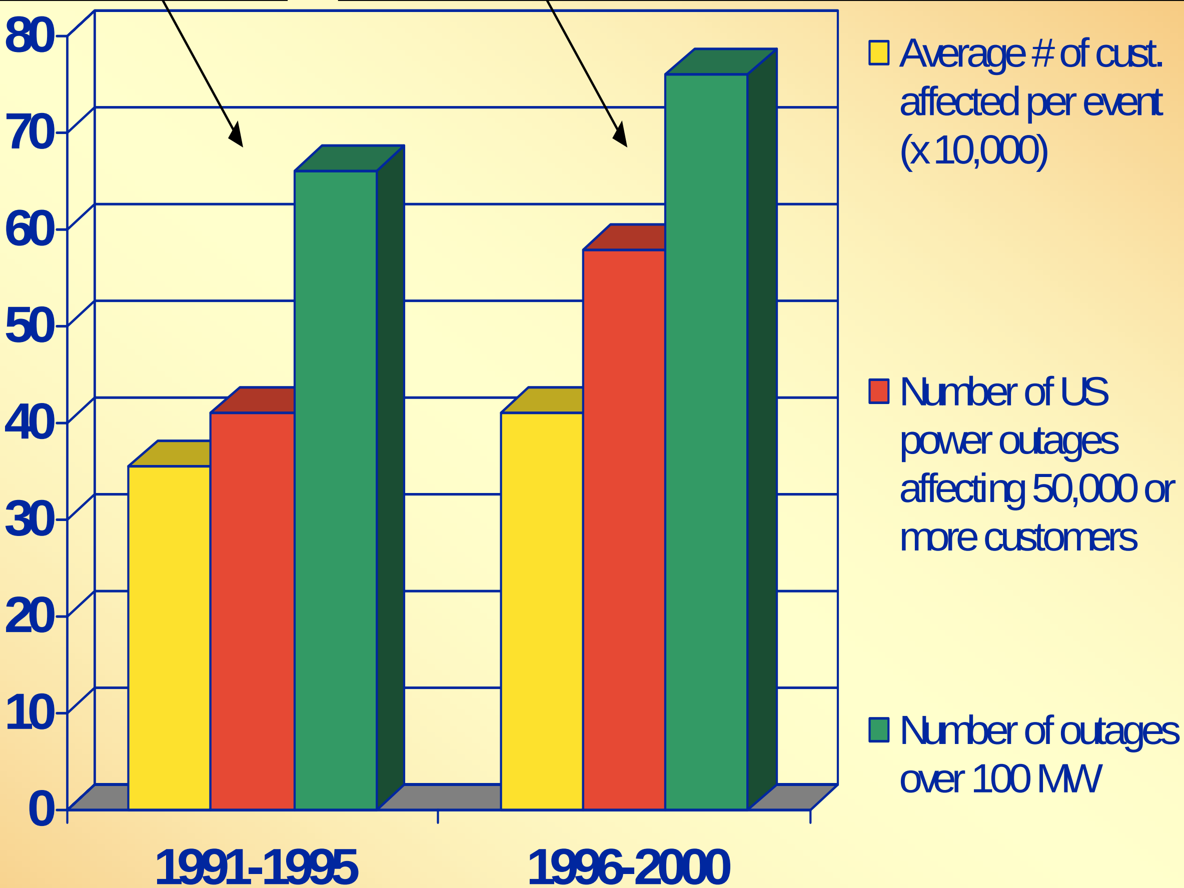
Source: "Historical Statistics of the Electric Utility Industry" and "EEI Statistical Yearbook" - *EEI*

Historical Analysis of U.S. outages (1991-2000)

66 Occurrences over 100 MW
798 Average MW Lost
41 Occurrences over 50,000 Consumers
355,204 Average Consumers Dropped

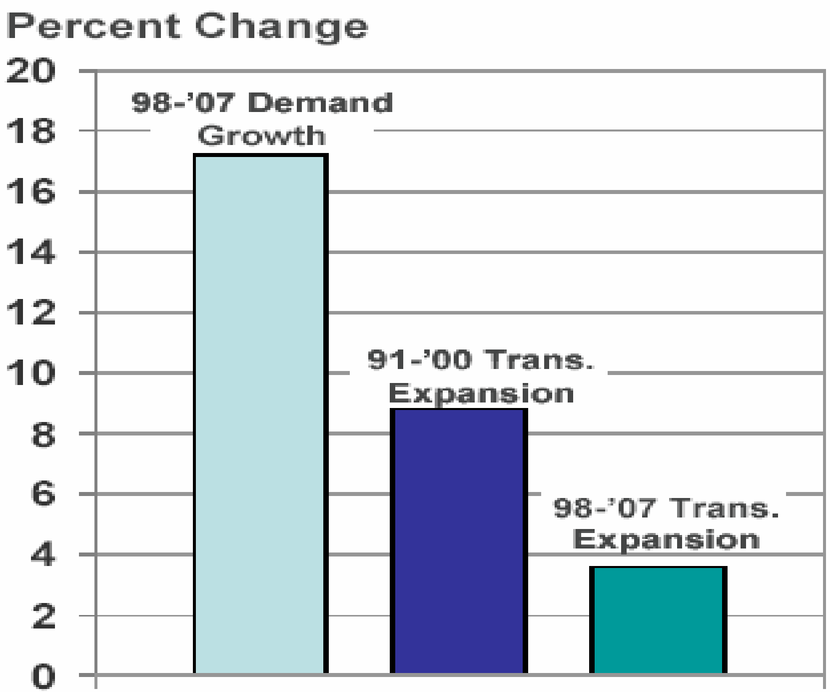
76 Occurrences over 100 MW
1,067 Average MW Lost
58 Occurrences over 50,000 Consumers
409,854 Average Consumers Dropped

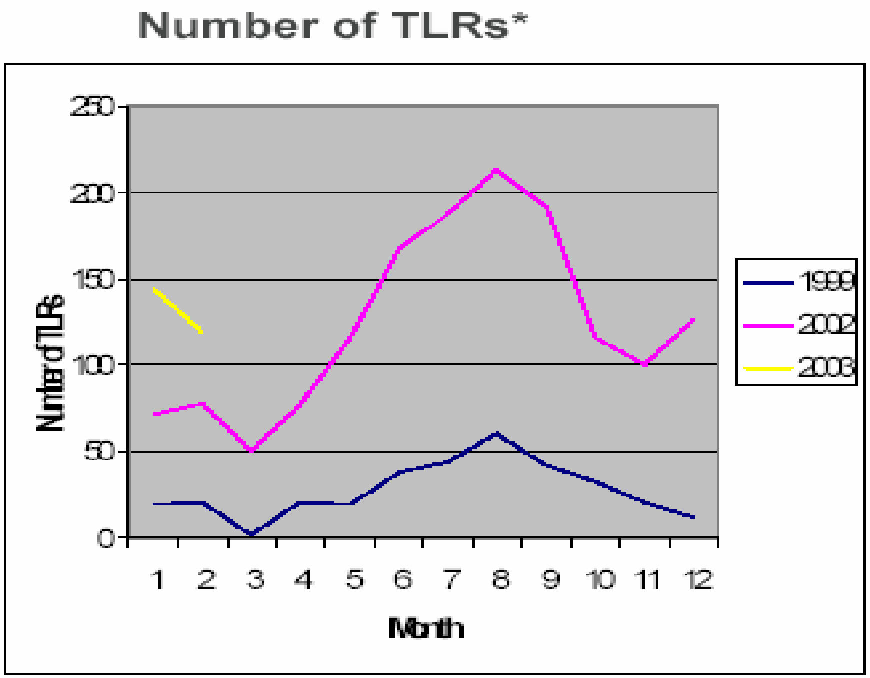
Increasing frequency and size of US power outages 100 MW or more (1991-1995 versus 1996-2000), affecting 50,000 or more consumers per event.



Data courtesy of NERC's Disturbance Analysis Working Group database

Transmission investment at half of 1975 level

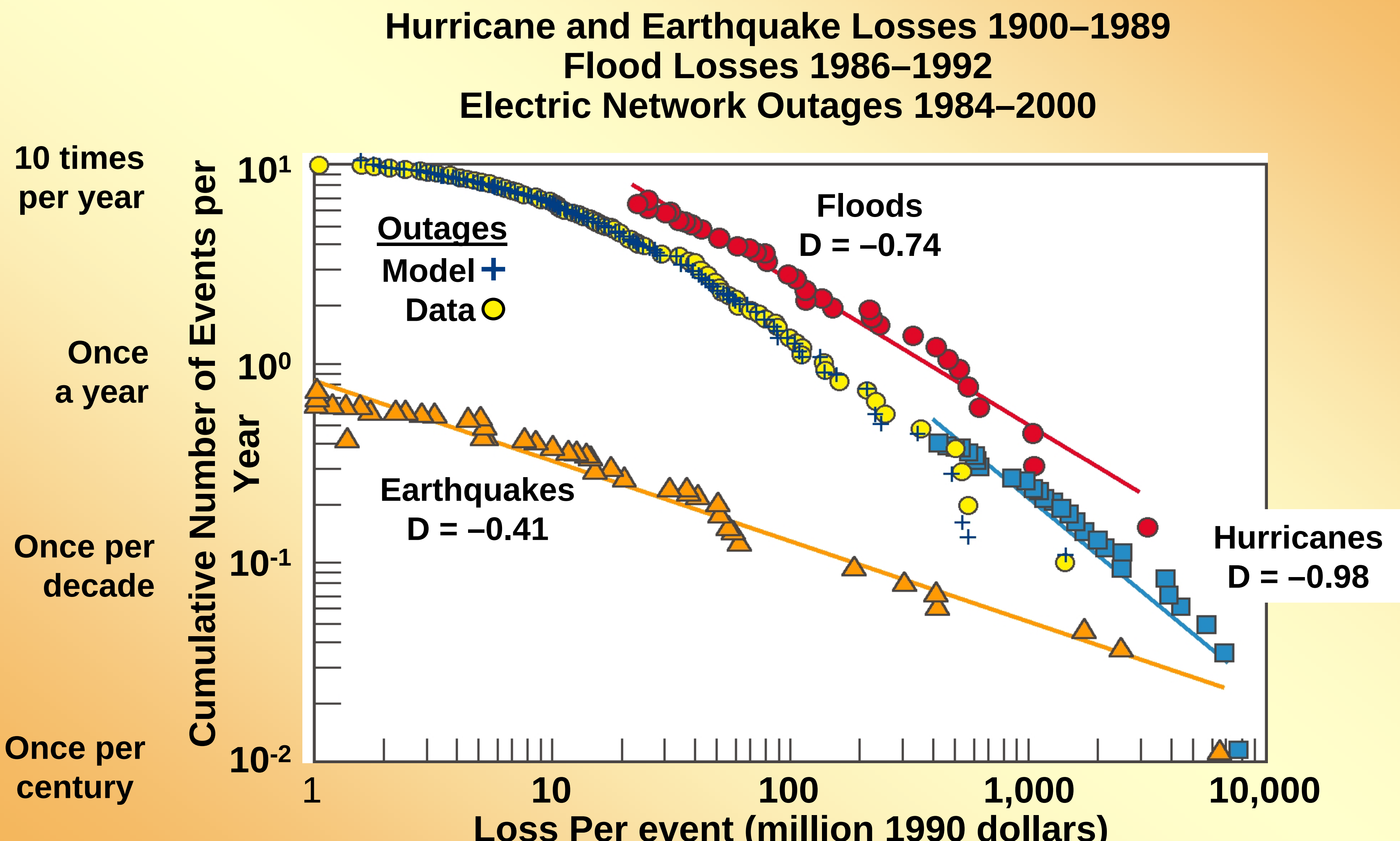




*Requests for Transmission Line Relief (TLRs) at Level 2 or higher

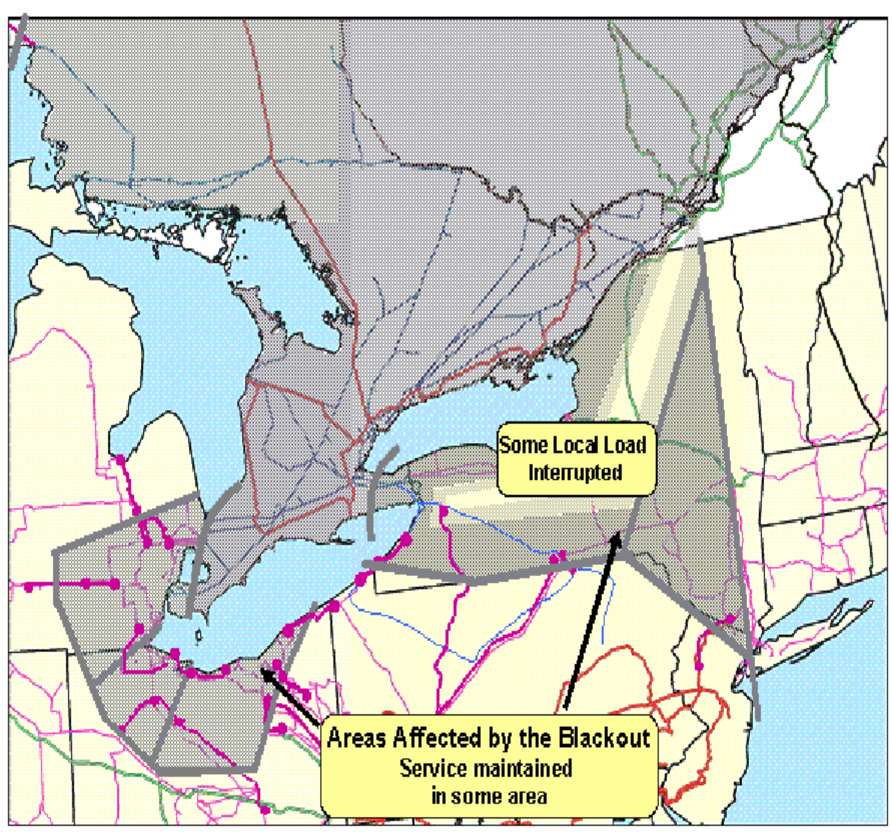
Inefficient markets provide inadequate incentives for infrastructure investment
– Boom-bust cycle may be taking shape in generation investment
– Congestion rising, as indicated by increase of TLRs
– Exercise of market power in California in summer of 2000 cost consumers $4 billion

Power Law Distributions: Frequency & Impacts of Major Disasters



Summary of August 14, 2003 Blackout Statistics

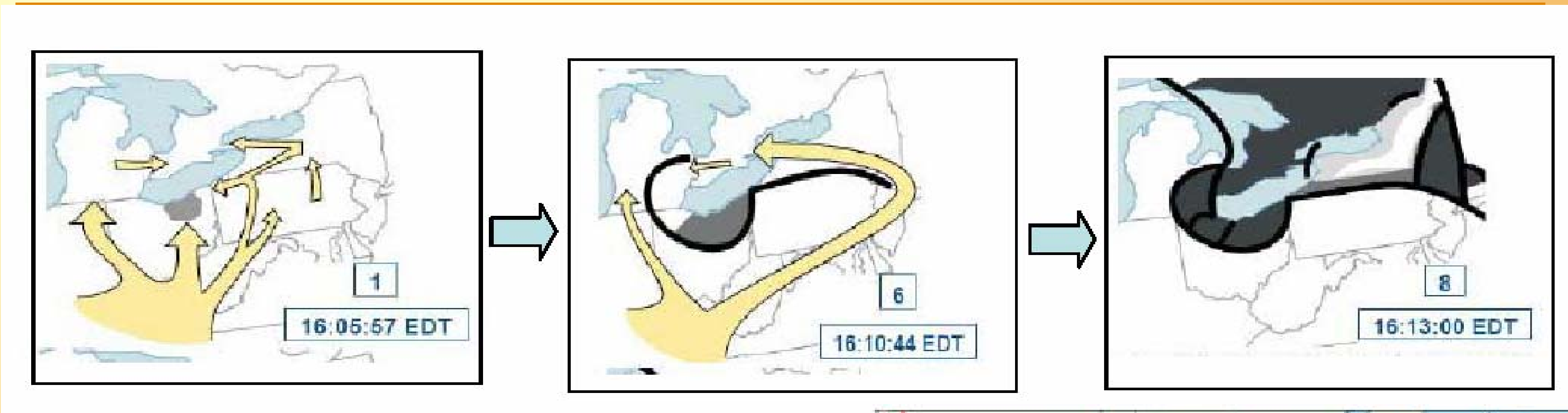
- Reported as affecting 50 million people
- 60-65,000 MW of load initially interrupted
  - Approximately 11% of Eastern Interconnection
- 531 Generators shut down at 263 plants
- Estimated $6.4B economic loss
  - $1B in NYC alone
- 8 states, 2 provinces
- Joint U.S.-Canada Task Force interim report published Nov. 19, 2003; root causes cited:
  - "Inadequate situational awareness" at First Energy Corp.
  - Failure to adequately trim trees in its transmission right-of way
  - Failure of reliability coordinators to promptly identify and deal with problems

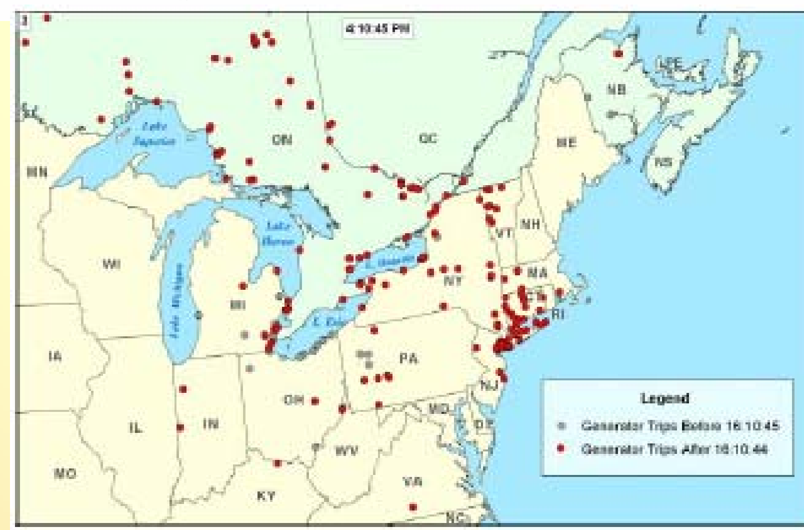


Affected Areas

Source: Joint U.S.-Canada Task Force Interim Report

Risk of Major System Failures



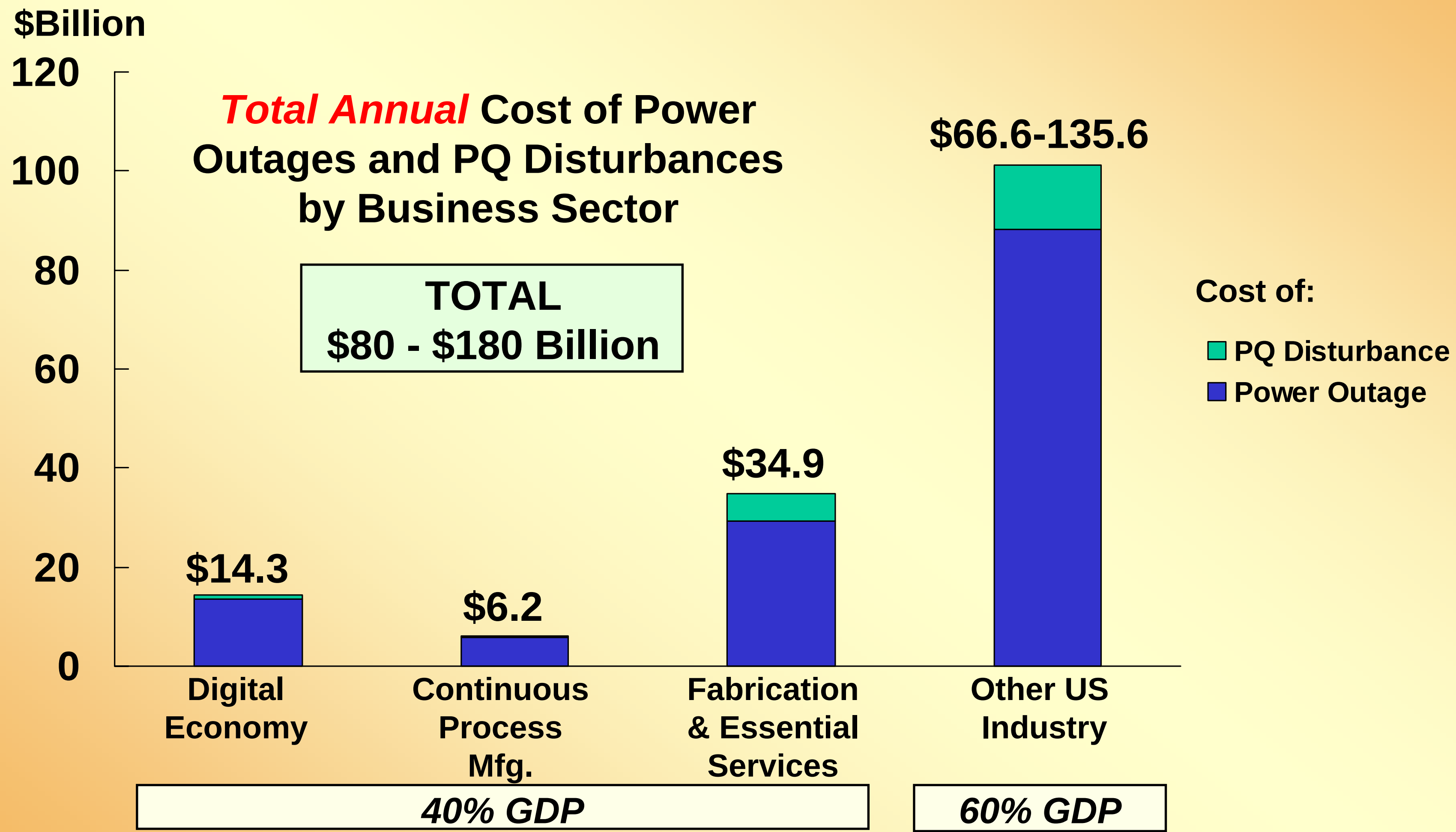


- **Six major blackouts occurred within six weeks in summer ’03**
  - **-112 million people affected in US, UK, Denmark, Sweden, & Italy**
  - **-Significant contributing factors were lack of coordination across system boundaries and slow response to emerging problems**

- **New mode of coordinated operation for real-time security assessment and control is needed**

Source: NERC and the Joint U.S.-Canada Task Force Report

A Toll Felt Throughout the U.S. Economy: Over $80 billion/year

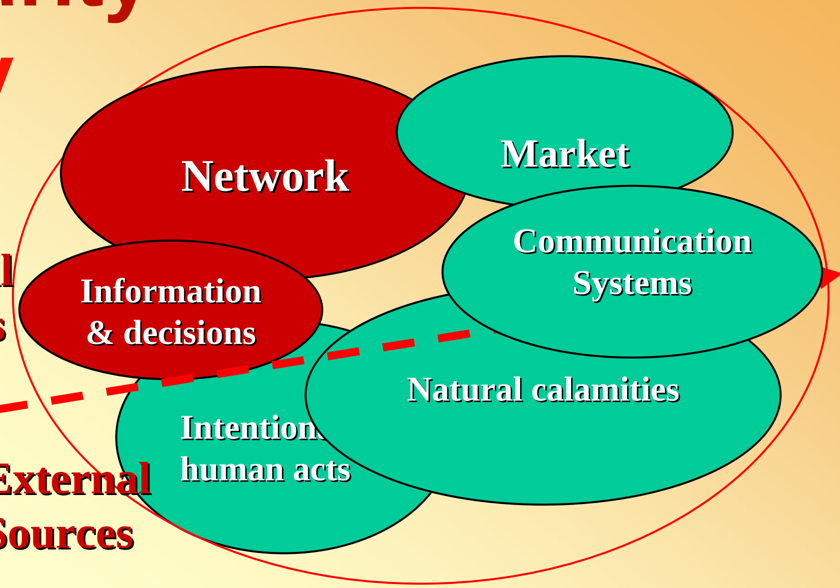


Source: Primen Study: The Cost of Power Disturbances to Industrial & Digital Economy Companies

Context for Recent Changes

- Energy infrastructure security issues in the wake of the 9/11 attack
- Western states power crisis and subsequent ongoing financial crisis
- Loss of investor confidence
- Restructuring slowdown and issues surrounding SMD
- Environmental issues and progress in addressing them
- Technology advances on a broad front -- but incentives to invest have not kept pace

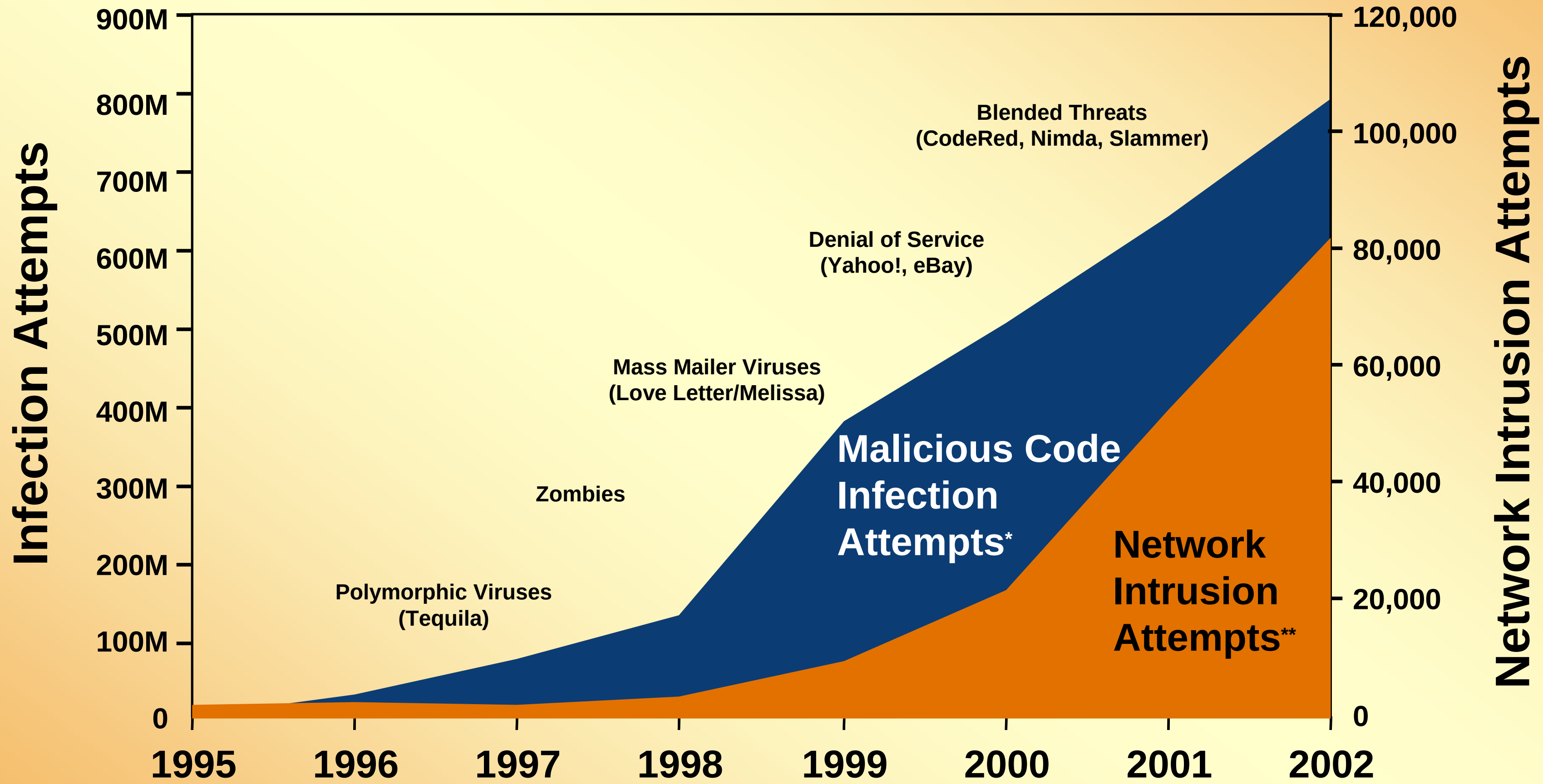
Context: **Threats to Security**
Sources of Vulnerability



• Transformer, line reactors, series capacitors, transmission lines...
• Protection of ALL the widely diverse and dispersed assets is impractical
-- 202,835 miles of HV lines (230 kV and above
-- 6,644 transformers in Eastern Intercon.
• Control Centers
• Interdependence: Gas pipelines, compressor stations, etc.; Dams; Rail lines; Telecom – monitoring & control of system
• Combinations of the above and more using a variety of weapons:
•Truck bombs; Small airplanes; Gun shots – line insulators, transformers; more sophisticated modes of attack…

• Hijacking of control
• Biological contamination (real or threat)
• Over-reaction to isolated incidents or threats
• Internet Attacks – Over 30,000 hits a day at an ISO
• Storms, Earthquakes, Forest fires & grass land fires
• Loss of major equipment – especially transformers…

Worldwide Attack Trends



*Analysis by Symantec Security Response using data from Symantec, IDC & ICSA; 2002 estimated

**Source: CERT

Electric Company Vulnerability Assessment

- **Conducted by 4 National Labs and consultant**
- **Able to assemble detailed map of perimeter**
- **Demonstrated internal and end-to-end vulnerabilities**
- **Intrusion detection systems did not consistently detect intrusions**
- **X-Windows used in unsecured manner**
- **Unknown to IT, critical systems connected to internet**
- **Modem access obtained using simple passwords**

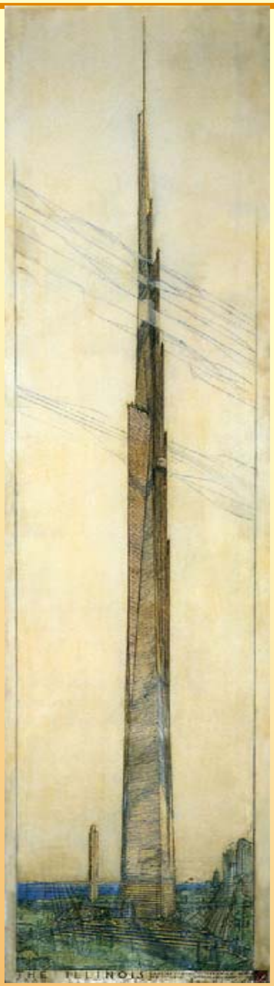
Much of the above determined from over 1200 miles away.

In Sum: Today's Grid

- Many vulnerabilities made evident
- Most common outages are concentrated in distribution lines (not primary transmission)
- Growing concerns with power quality

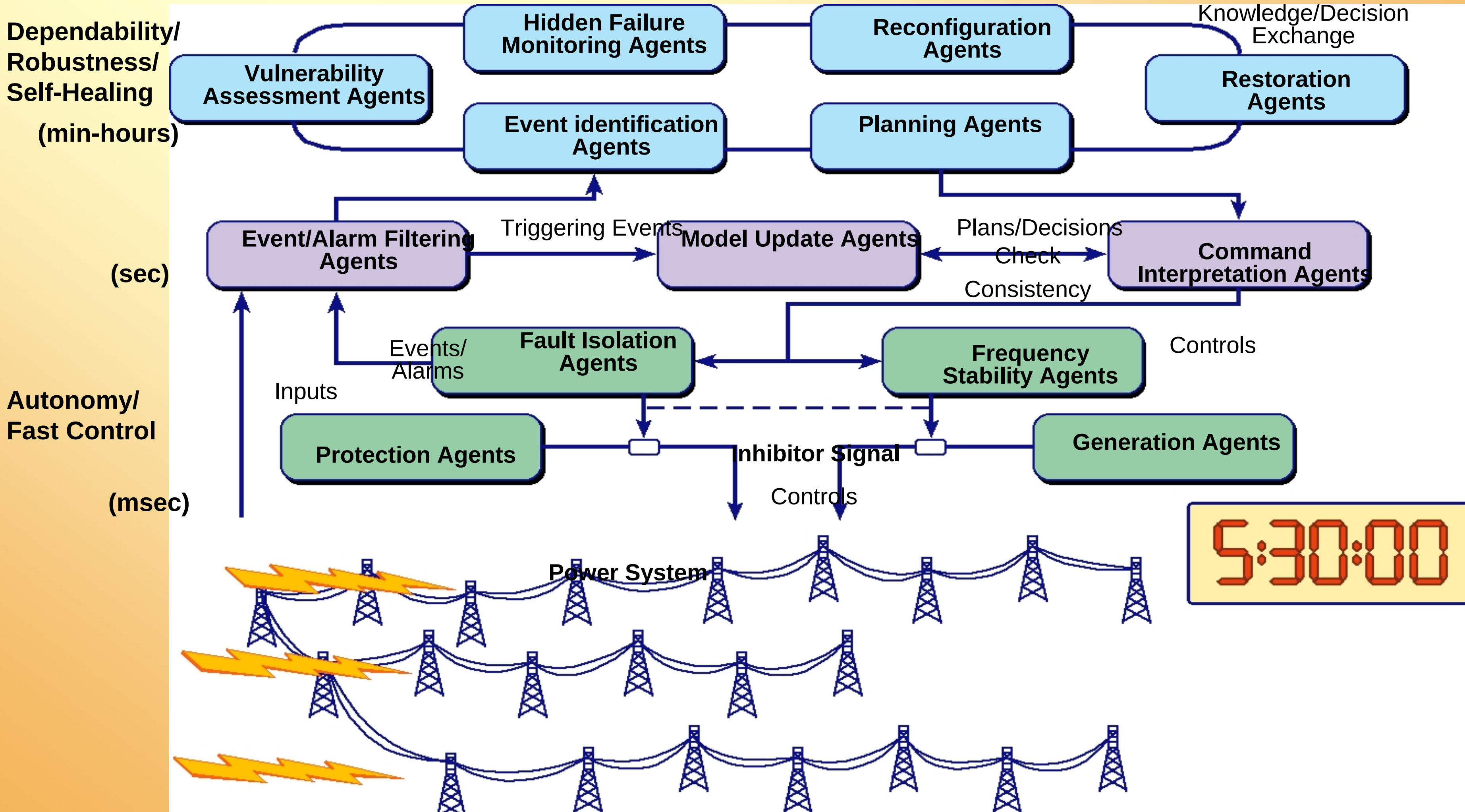
Major outages of August and September 2003 in the US, UK, Italy…

The “Ideal” Grid



- Intelligent, “self-healing” grid concept builds on:
  - Anticipation of disruptive events
  - Look-ahead simulation capability
  - Fast isolation and sectionalization
  - Adaptive islanding

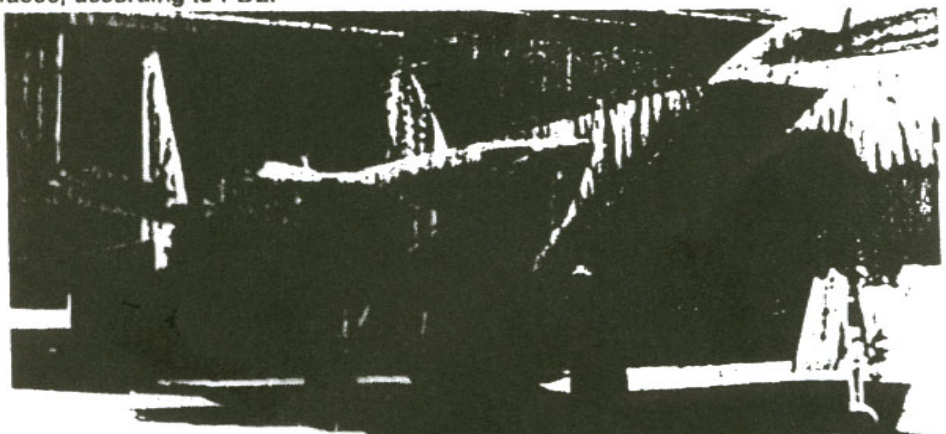
"Self-Healing" Grid



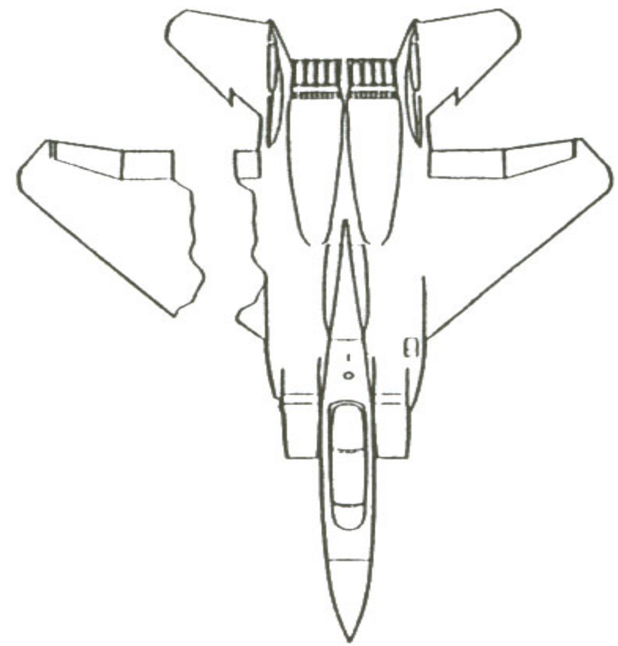
Background:
The Self Healing Grid

Background: The Self Healing Grid 1994-1998: The Case of the Missing Wing

Believe it or not, this one made it back! This F-15, with half its wing missing, is a good example of what is currently considered an "unflyable" aircraft. However, the pilot's success in bringing it home helped to inspire a new program at Aeronautical Systems Division's Flight Dynamics Laboratory aimed at enabling future fighter pilots to fly aircraft with severely damaged control surfaces. The pilot of this F-15 configured in unusual ways the control surfaces that were still working to compensate for the damaged wing. The FDL program will make this "survivors" reaction automatic to the aircraft. Therefore, flying a damaged aircraft will be much easier on the pilot. Through a self-repairing flight control system nearing development, a computerized "brain" will automatically reconfigure such surfaces as rudders, flaperons, and ailerons to compensate for grave damage to essential flying surfaces, according to FDL.

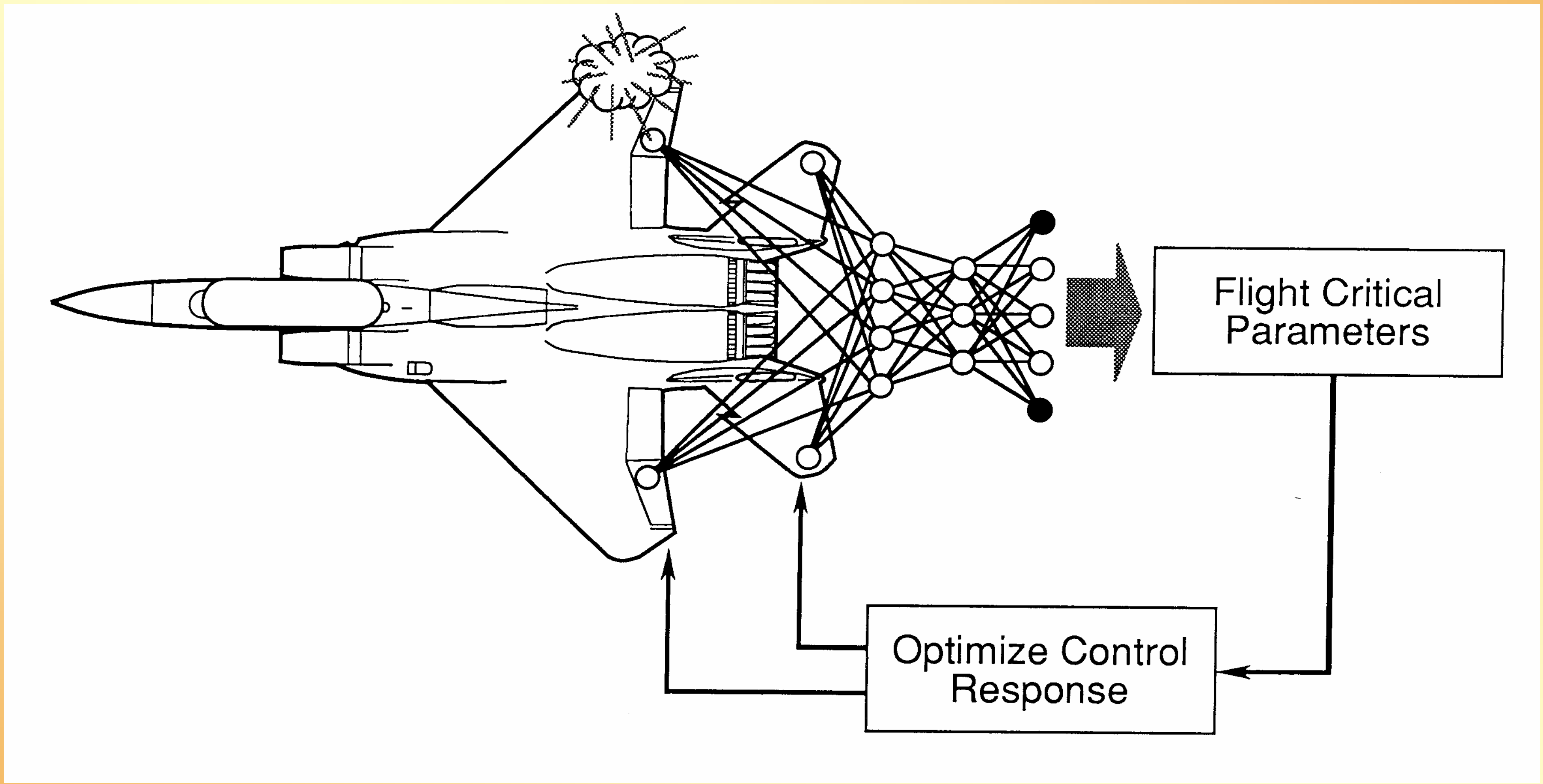


Only smart work by the pilot and the unique combination of interworking control surfaces on the F-15 brought this one back alive. With old-fashioned conventional ailerons and horizontal stabilizer, it couldn't have happened.



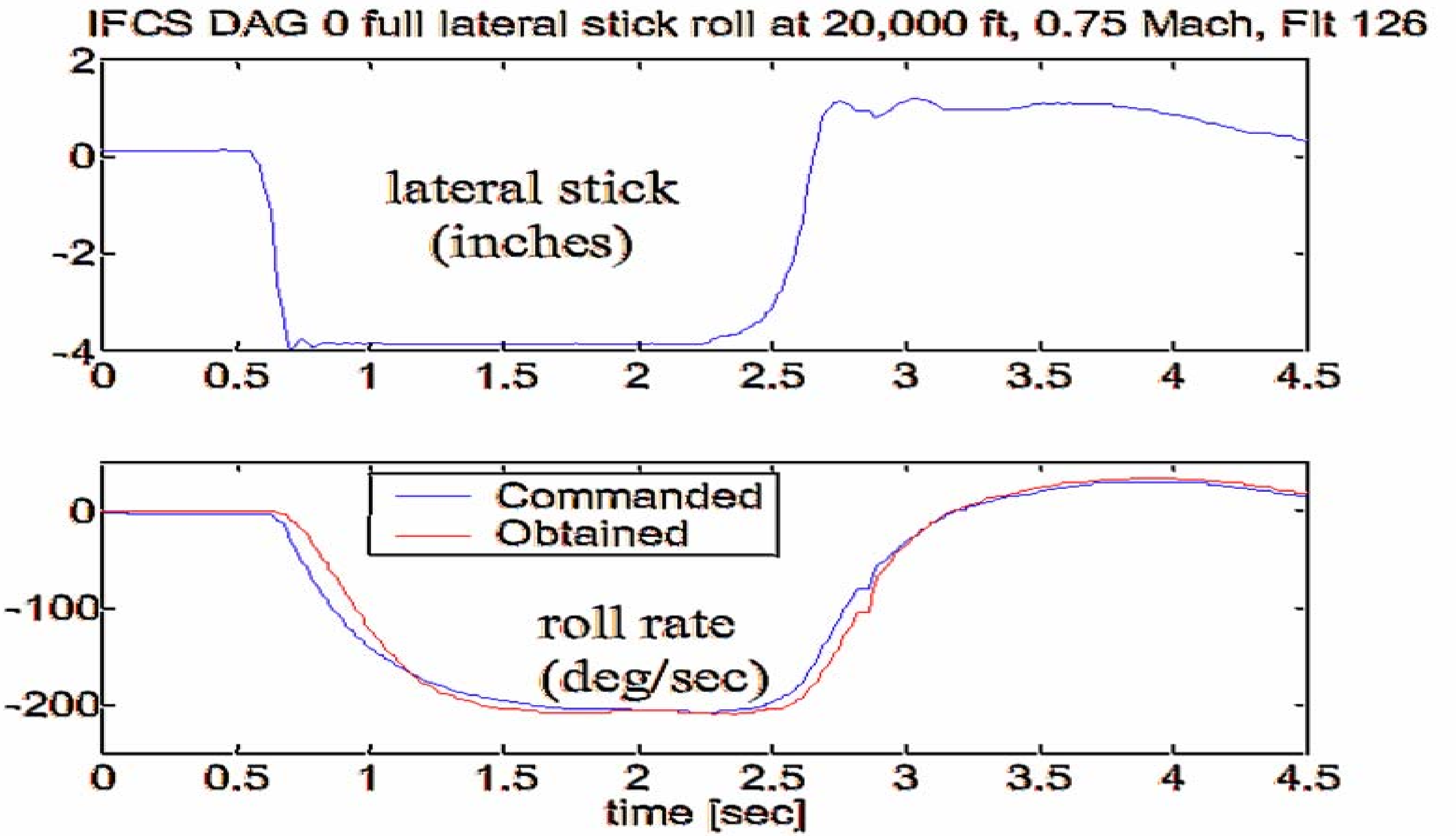
NASA/MDA/WU IFCS: NASA Ames Research Center, NASA Dryden Flight Research Center, Boeing Phantom Works, and Washington University in St. Louis.

Goal: Optimize controls to compensate for damage or failure conditions of the aircraft*



NASA/MDA/WU IFCS

Roll Axis Response of the Intelligent Flight Control System



Accomplishments in the IFCS program

- The system was successfully test flown on a test F-15 at the NASA Dryden Flight Research Center:
  - Fifteen test flights were accomplished, including flight path control in a test flight envelope with supersonic flight conditions.
  - Maneuvers included 4g turns, split S, tracking, formation flight, and maximum afterburner acceleration to supersonic flight.
- Stochastic Optimal Feedforward and Feedback Technique (SOFFT) continuously optimizes controls to compensate for damage or failure conditions of the aircraft.
- Flight controller uses an on-line solution of the Riccati equation containing the neural network stability derivative data to continuously optimize feedback gains.
- Development team: NASA Ames Research Center, NASA Dryden Flight Research Center, Boeing Phantom Works, and Washington University.

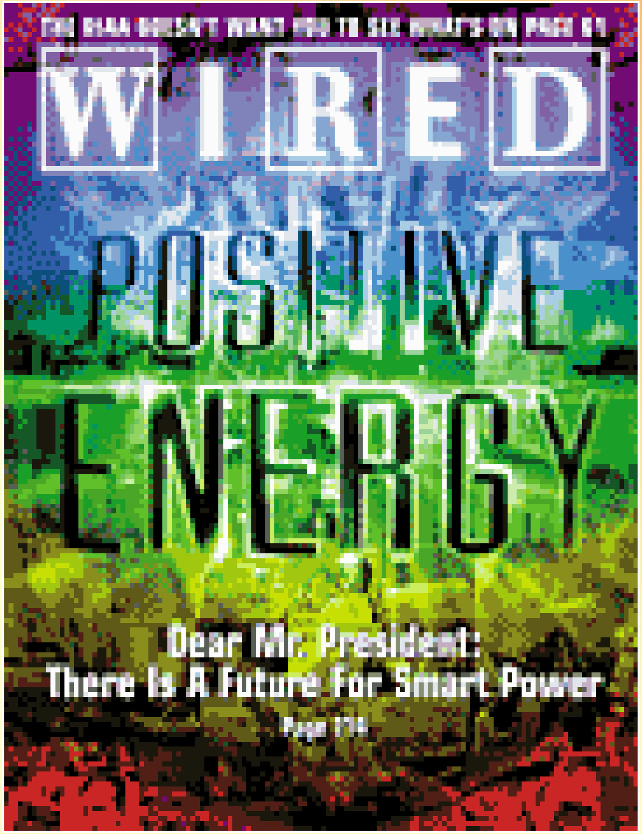
Big Picture: **"Not to sell light bulbs, but to create a network of technologies and services that provide illumination…"**

The Energy Web:

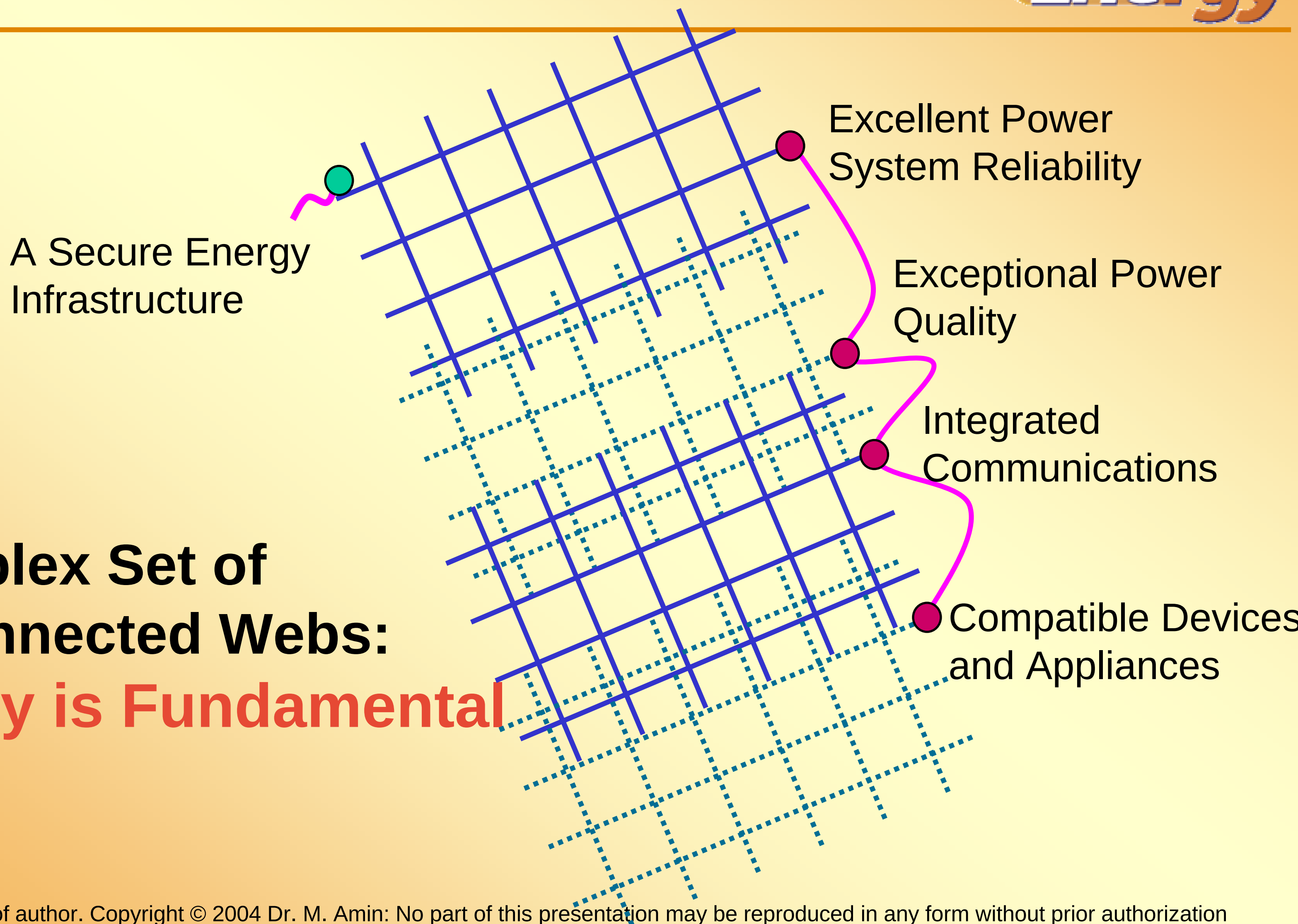
"The best minds in electricity R&D have a plan: Every node in the power network of the future will be awake, responsive, adaptive, price-smart, eco-sensitive, real-time, flexible, humming - and interconnected with everything else."

-- Wired Magazine, July 2001

http://www.wired.com/wired/archive/9.07/juice.html

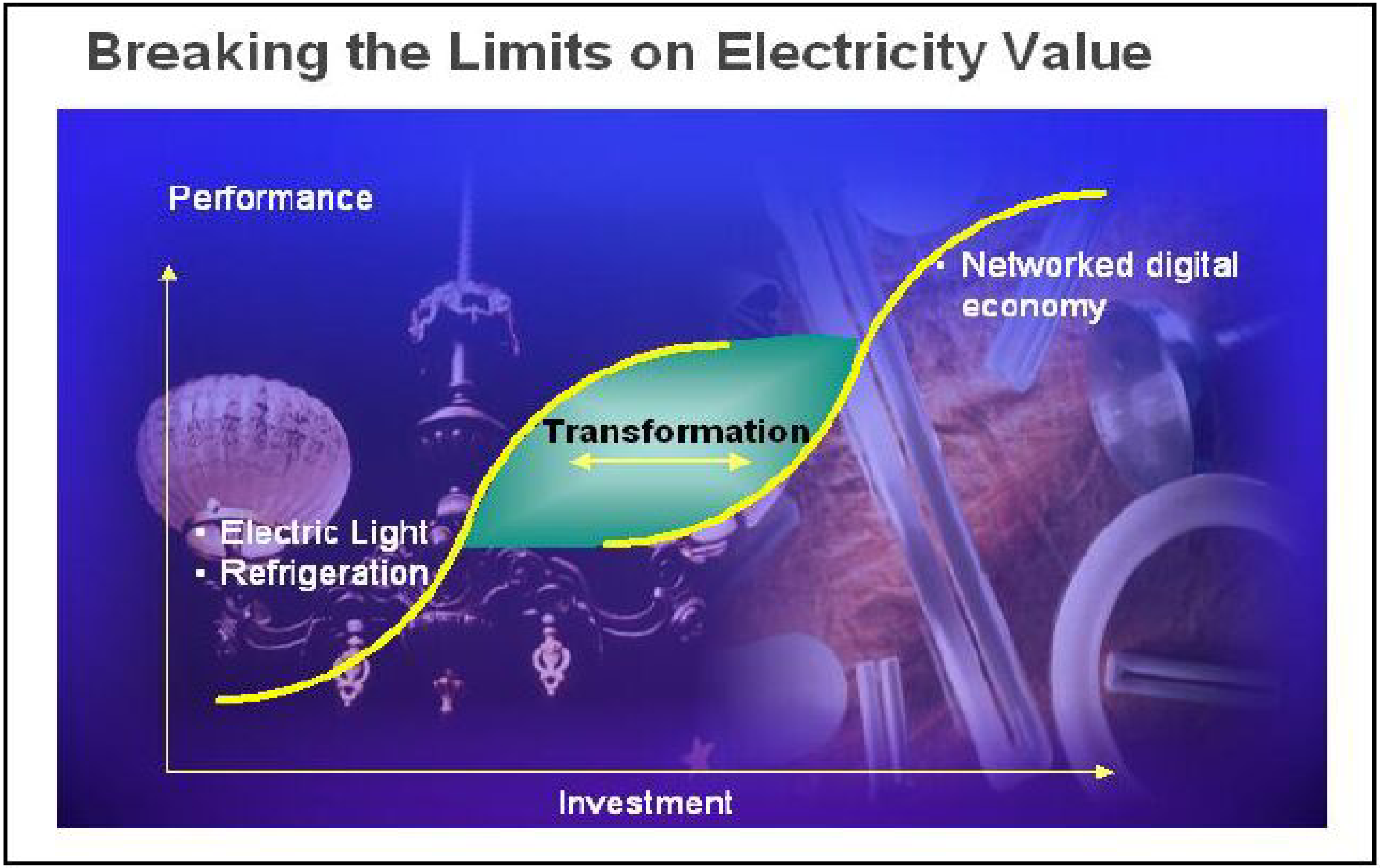


The Technology Challenge: The Infrastructure for a Digital Society

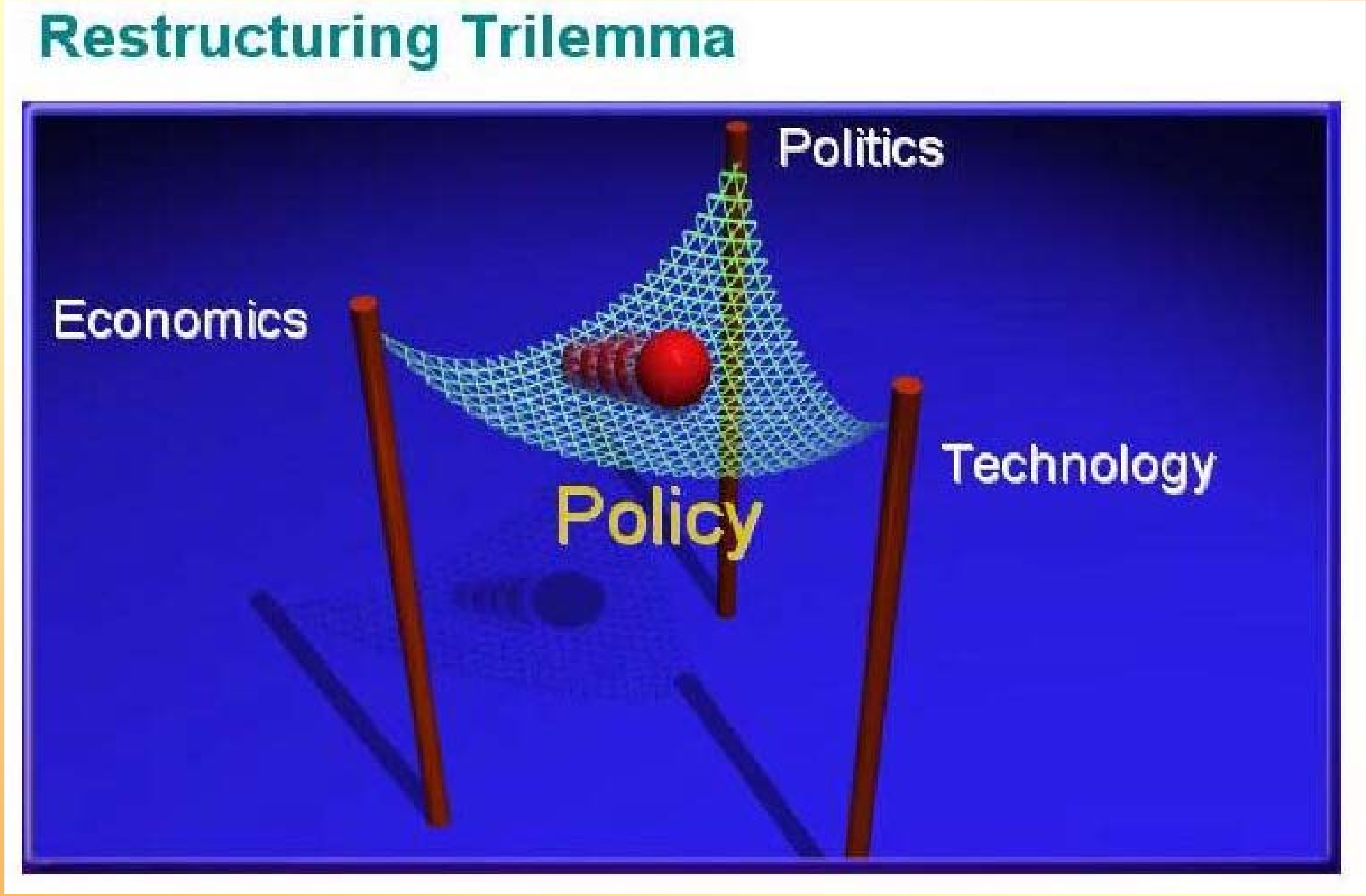


A Complex Set of Interconnected Webs:
Security is Fundamental

Investment Required

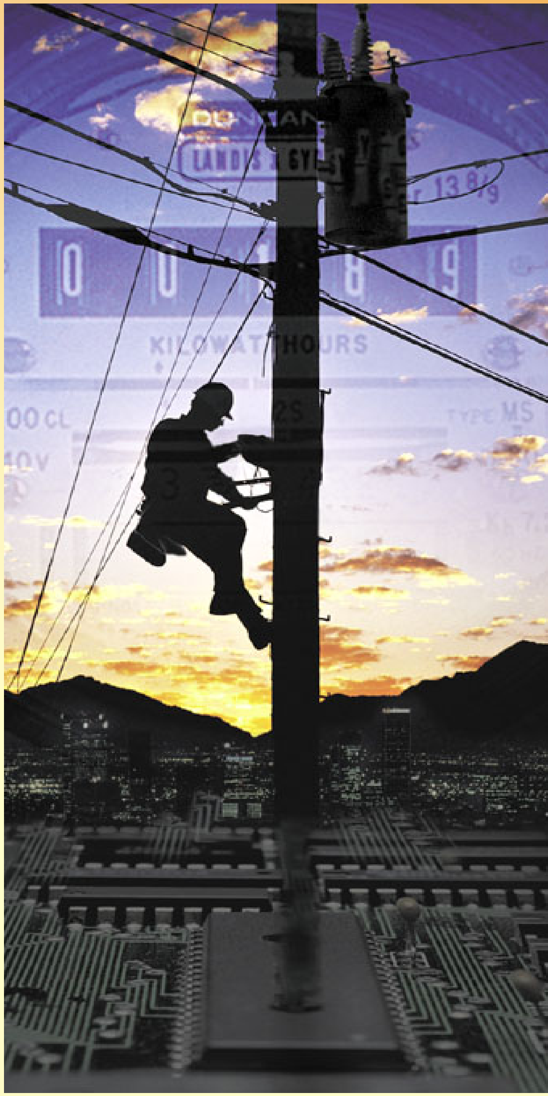


Unresolved Issues Cloud Planning for the Future



Recommendations

- **Establish an intelligent "self-healing grid" as a national priority**
- **Authorize increased funding for R&D and demonstrations**
- **Revitalize the national public/private electricity infrastructure partnership needed to fund grid improvements**
- **Be prepared! No matter how hard we try to prevent it, outages WILL occur**



Shaping the Future: Technology Must Support This Transformation

Several failure modes persist…

But creating a "better" grid is no longer a distant dream, as considerable progress is being made.

We'll be successful!

Thank You!

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